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1. Your reference	D071949PGB	
2. Patent application number *(The Patent Office will fill in this part)*	14 JUN 2003	0313880.7
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	Colt Systems Limited 3 The Acres Stokesley North Yorkshire TS9 5QA	
Patents ADP number *(if you know it)*		7653541001
If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom	
4. Title of the invention	ROPE TERMINATOR	
5. Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Marks & Clerk Alpha Tower Suffolk Street Queensway Birmingham B1 1TT	
Patents ADP number *(if you know it)*	18002	

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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11. I/We request the grant of a patent on the basis of this application.

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David CARPENTER 0121 643 5881

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ROPE TERMINATOR

This invention relates to a rope terminator for use with high strength, low stretch, parallel core synthetic ropes.

Rope terminators are sometimes referred to as "Rope Fittings" and are attached to an end of a rope to provide a means for securing the rope end to an anchor point. The rope terminator of the present invention is particularly intended for use with parallel core ropes formed from high strength, low stretch synthetic fibres for example Aramid fibres, a particular example being Kevlar^{tm}, and those consisting of parallel PBO (p-phenylylene-2'6-benzobisoxazole) fibres, an example of which is Zylon^{tm}.

The term "parallel core" in relation to ropes indicates that the fibres of the rope extend parallel to one another as a "hank" of fibres usually restrained between their ends by an outer sheath or binding. However in so far as the terminator is concerned the fibres need to be parallel only in the immediate proximity of the terminator and so it is to be understood that ropes where the fibres are wound or even braided can be used with the terminator provided that the fibres at the terminator end region of the rope are arranged generally parallel to one another. Moreover while a terminator in accordance with the present invention is intended for use with Aramid or PBO fibre ropes, it can be used with ropes formed from fibres of other materials.

A conventional rope termination is illustrated in British Patent 1341013 and in Figure 1 of the accompanying drawings. A tapering wedge member or spike 3 traps fibres of the rope 9 against the inner surface of an internally

tapering metal body 1. As the tension in the rope increases the wedging action between the wedge member, the fibres, and the barrel increases as the wedge member is drawn deeper into the tapering barrel. The arrangement illustrated in Figure 1 and British Patent 1341013 is suitable for terminating steel strand ropes, natural fibre ropes, and ropes constructed from certain synthetic fibres.

High strength, low stretch fibres are used for ropes in applications where high strength and/or low stretch combined with low weight is critical. They are typically used in applications where steel rod or steel wire would conventionally be used but are deemed too heavy, including by way of example any high performance sporting equipment where weight reduction is generally of prime concern, of which yacht rigging is a prime example. Although rope terminators in accordance with the present invention can find use in a wide variety of applications, consideration of the yachting industry will explain the trend towards increased use of modern high strength, low stretch fibre rope materials such as Aramid and PBO materials. Over the past few years the use of steel for deck hardware (pulleys, winches, furling systems and the like) has been replaced by composite materials, such as carbon fibre reinforced plastics materials. Masts and spars, conventionally formed from aluminium, are now increasingly formed from carbon reinforced synthetic resin materials.

The yacht designer's aim is to reduce not simply the overall weight of the yacht, but also to reduce the proportion of the weight of the yacht which is disposed above the yacht centre of gravity. As a simplified example, consider a 20 metre yacht with a 25 metre mast rigged for racing will probably use

steel strand ropes or steel rod for its standing rigging, the ropes being terminated with terminators of the kind shown in British Patent 1341013 also formed from steel. Such standing rigging will have a weight of approximately 1.4 kg/m. Approximately 100 metres of the such rigging will be required and if the steel standing rigging could be replaced with a PBO rope of the same strength then the weight of the standing rigging would be reduced from approximately 1.4 kg/m to less than 0.2 kg/m. There would thus be a weight saving of over 100 kg and in the case of standing rigging then the weight of the standing rigging can be considered to be nominally located half way up the height of the mast (12.5m) and at this height the turning moment of a 100kg weight is very significant in the handling of the yacht. Furthermore, any reduction in weight in the standing rigging allows approximately a five fold reduction in keel weight and thus it can be seen that by replacing steel standing rigging with PBO fibre rigging an overall weight reduction of 600 kg could be achieved. Additionally the PBO ropes will have a cross-sectional area approaching half that of an equivalent steel rope/rod, and consequently the aerodynamic drag or windage presented by PBO ropes will be considerably less.

In addition to the performance increase attributable to simply reducing the overall weight of the yacht there would be performance and safety improvements in relation to the responsiveness of the yacht given the lower centre of gravity, reduced draft of the hull, and "tighter" rig. As PBO ropes have a higher elastic modulus (and therefore lower stretch) than steel, combined with a reduction in weight of 90% compared to steel, they would form excellent replacements to steel ropes/steel rods in standing rigging where minimising lateral mast movement is critical. However this is not

generally possible as the use of a conventional terminator of the kind shown in Figure 1 and British Patent 1341013 is highly problematic in relation to PBO fibre ropes and consequently PBO is generally not used in conventional standing rigging. The present invention, configured for PBO ropes, permits PBO based ropes to be used in such situations. Although Aramid ropes can be terminated with conventional terminators of the kind shown in Figure 1 and British Patent 1341013 Aramid ropes are not generally used in shrouds and lateral mast support as they have a lower elastic modulus (and therefore higher stretch) than steel which would induce performance handicaps and instability in the rig. However Aramid ropes are used in the fore and aft plane of the yacht (for example as checkstays and running backstays) where stretch is not as critical but a reduction in weight aloft remains desirable. In these instances where reduction in weight is the prime driver, use of the present invention would offer further weight savings of up to 50% in terminator/fixture weight.

As mentioned above the invention can find use in a variety of different environments where Aramid and/or PBO fibre ropes are or could be used and the invention may enable such ropes to be utilized in applications where their use is desirable but currently difficult or impossible owing to the lack of satisfactory terminations. A non-exhaustive list of possible applications for the invention includes Bridge stays, Antennae supports, Lightweight and temporary building structures, Glass walls/ceilings, Suspended electrical systems, Overhead electrically driven tram & train systems, Offshore mooring systems for example Floating Production, Storage & Offloading (FPSO) vessels, and Mobile Drilling Units (MDU).

It is found that both Aramid, and even more so, PBO fibres exhibit their optimum tensile strength while the fibres are maintained as close to a straight configuration as possible. It has been recognised by the present Inventor that fibres have a Fibre Failure Angle (FFA) when under tensile stress, beyond which the fibres should not be bent if optimum tensile strength characteristics of the fibres are to be maintained. It will be recognised that fibres within a terminator bend in a "soft" manner at the point at which they exit the sheath of the rope (the sheath can expand as the fibres are put in tension so that the bend is spread over a radiused finite distance) and again in a "hard" fixed manner at the point where they begin to be gripped between the wedge member and the barrel of the terminator. Both of these bend angles are largely determined by the internal cone angle of the barrel of the terminator. Fibres such as Aramid and PBO have a relatively small FFA and so the cone angle of the barrel of the terminator should be correspondingly small. However, there is a minimum length of fibre which must be gripped between the barrel and the wedge member to prevent terminator failure through fibre slippage and this length increases as the cone angle of the barrel decreases. This, coupled with increasing rope diameters, for larger load capacities, means that the terminator barrel becomes quite large, and when formed in steel carries with it a significant weight penalty.

Furthermore, the inner surface of the barrel is required to have a high surface finish so as to exhibit a lower frictional grip against the fibres than that exhibited between the fibres and the wedge member. As the size of the barrel increases and the cone angle decreases, the difficulty of producing an appropriate surface finish on the interior of the barrel also increases to the

point at which it is at best economically non-viable, and at worst impossible, to produce a satisfactory steel barrel for a PBO rope terminator.

It is an object of the present invention to provide a rope terminator which is suitable, in particular, for terminating Aramid and PBO fibre ropes.

In accordance with one aspect of the present invention there is provided a rope terminator comprising, an elongate hollow barrel formed from a fibre reinforced synthetic resin material, the barrel having therein a rope receiving passage, and said passage having a first end region from which the rope to be terminated extends in use, and an opposite, second end region, the passage tapering in internal diameter from a minimum at said first end region to a maximum at said second end region, a tapering wedge member for insertion into said passage of the barrel to trap fibres of the rope between the outer tapering surface of the wedge member and the inner tapering surface of said passage, the wall of said passage and the surface of the said wedge member being such that the frictional drag of the rope fibres on the wall of said passage is less than the frictional drag of the fibres on the surface of the wedge member when the wedge member traps fibres against the wall of the passage, said barrel having an outer surface region overlying a wider end region of said passage, said outer surface region of said barrel tapering in diameter in the same direction as the direction of taper of said region of said passage which it overlies, and, the terminator further including a hollow outer body member having therein a tapering passage within which said outer tapering surface region of said barrel is received, whereby said outer body member encases said outer surface region of said barrel and supports that region of the barrel against bursting loads imposed thereon by the action of

said wedge member trapping rope fibres against the wall of said wider end region of said passage, and provides a means of attaching the terminated rope to an anchor point or the like in use.

Preferably said outer body member is formed from steel or similar high tensile strength machineable material.

Desirably said outer body member is arranged releasable to receive a plurality of alternative anchorage components.

Preferably the fibre reinforcement of the material of the barrel is provided by one or more wound PBO fibres.

Preferably the taper angle of the wedge member varies along the length of the wedge member such that throughout the length of the wedge member the area of the annulus defined between the outer surface of the wedge member and the inner surface of the passage is constant.

In the accompanying drawings:

Figure 1 is a diagrammatic cross sectional view of a conventional rope terminator generally of the kind disclosed in British Patent 1341013;

Figure 2 is a view similar to Figure 1 of a rope terminator in accordance with one example of the present invention;

Figure 3 is an exploded cross sectional view of the terminator of Figure 2;

Figure 4 is a diagrammatic side view of a fully assembled terminator, and;

Figure 5 is a diagrammatic view of two alternative fixing component arrangements.

Tables 1 to 3 illustrate suitable dimensions for the body; barrel; and spike (wedge member) components respectively of terminators in accordance with examples of the present invention designed for use with Zylon™ ropes, and.

Tables 4 to 6 illustrate suitable dimensions for the body; barrel; and spike (wedge member) components respectively of terminators in accordance with examples of the present invention designed for use with Aramid ropes. In Tables 1 to 6 the rope size figures denote the Nominal Breaking Load of the rope in Tonnes and the dimensions are in Millimetres.

The conventional terminator shown in Figure 1 has a hollow, elongate stainless steel body 1 of circular cross-section, formed internally with a passage 2 having a first end 2a from which the rope to be terminated extends in use, and an opposite, second end 2b. The passage 2 tapers in diameter from a maximum adjacent the end 2b, to a minimum adjacent the end 2a, and at its wider end the body 1 receives a screw threaded adaptor 2c whereby any one of a plurality of alternative fixing components can be secured to the terminator, to facilitate the connection of the terminator to a variety of different anchor points.

An elongate tapering wedge member of circular cross-section is received within the passage 2, and in use acts to trap fibres of the rope to be terminated, which are distributed around the wall of the passage 2, against the wall of the passage 2. The surface finish of the interior of the passage 2 is arranged to be smooth, such that the frictional drag between the rope fibres

and the wall of the passage 2 is significantly less than the frictional drag between the fibres and the outer surface of the wedge member 3 whereby as the load on the rope increases the fibres will tend to slide relative to the wall of the passage, dragging the wedge member 3 with them, and thus increasing the clamping force which the wedge member 3 applies to the fibres against the wall of the passage 2.

Where the Fibre Failure Angle (FFA) of the rope fibres is such that the taper angle of the passage 2 can be relatively steep and where the overall diameter of the rope is relatively small, then the length of the body 1 can be correspondingly short although still sufficient to achieve the necessary frictional drag between the fibres and the wedge member. It will be recognised that as cone angle increases then the effective unit clamping force on the fibres increases but the frictional drag on the fibres does not increase and so frictional drag could become a limiting factor in length reduction with increasing cone angle. Conversely the unit clamping force decreases with decreasing cone angle so necessitating length increase to ensure sufficient total clamping force. However, as the FFA of the fibres decreases, and the overall diameter (and hence the nominal breaking load) of the rope increases then the length of body 1 which is necessary to provide the necessary clamping length (the length over which the wedge member 3 clamps the fibres against the wall of the passage 2) increases to such an extent that the weight of the steel body 1 would be prohibitive, and the manufacturing processes necessary to produce a body 1 of the necessary length, with the required smooth finish to the wall of the passage, become economically prohibitive, or in some cases impossible by current manufacturing techniques. In particular, the formation of the appropriate smooth surface

finish on the interior of an extremely long tapering passage in an elongate hard steel body 1 is extremely difficult and expensive to achieve.

The forgoing disadvantages are minimised or obviated by the present invention an example of which will now be described with reference to Figures 2 and 3 of the accompanying drawings.

The rope terminator of Figure 2 is of circular cross-section and comprises an outer, steel body 11 receiving an inner barrel 12 formed from a wound fibre reinforced epoxy resin material. Although winding a fibre reinforcement of the barrel is the preferred construction method it is believed that the fibre reinforcement could be provided by other methods such as the use of a three dimensional knitted fibre sock or braid or a fibre wrapping technique. However the wound fibre method is concentrated upon in the following description.

The barrel 12 is of constant wall thickness throughout its length although in some applications a varying wall thickness could be used provided a necessary minimum thickness to achieve the desired strength exists throughout the barrel length. The barrel tapers from a minimum diameter at an end 12a from which a rope to be terminated extends in use, to a maximum at its opposite end 12b. The taper angle of the internal passage 13 of the barrel 12 and its surface finish are critical but are relatively easily achieved, irrespective of the axial length of the barrel 12, by forming the barrel by winding a fibre, or a plurality of fibres, on a rotating mandrel coated with a suitable release agent, while impregnating the fibres with an epoxy resin material which, in the completed barrel 12 binds the fibres into a composite

body. The fibre may be wet with epoxy resin by passing through a bath or the like of liquid resin just prior to laying the fibre on the mandrel. As an alternative the fibre could have been pre-impregnated or coated with resin in a tacky state at room temperature, the resin being heated to a flowable state as part of a curing process so as to flow into and wet the whole of the fibre matrix prior to the resin curing. The outer surface of the mandrel has the appropriate taper angle and surface finish, and it will be recognised that such a taper angle and surface finish can readily and cheaply be achieved on the exterior surface of a mandrel of circular cross-section.

As will be apparent, in use the barrel 12 must accommodate hoop or bursting stresses imposed thereon by a wedge member 14 introduced therein in use. The great majority of the strength of the barrel 12 in accepting such bursting loads is provided by the wound fibre reinforcement, and thus in order to reduce the weight of the barrel, and the wall thickness of the barrel, as much as possible it is desirable to use a reinforcing fibre which is both strong and inelastic. Of all currently available reinforcing fibres a high modulus PBO fibre, conveniently HM Zylon™ is chosen as a reasonable selection for anticipated working environments. It is to be recognised however that the use of other fibres as the fibre reinforcement of the barrel 12 is not excluded. For example, cheaper Aramid fibres could be used but this would add significantly to the wall thickness and overall weight of the terminator. Similarly certain high grades of carbon fibre could be used, however most of these would also require a greater wall thickness and would generally be more brittle possibly restricting their application or requiring an aramid coating for impact resistance. Carbon fibres also conduct electricity which in saltwater applications where they are in contact with or close proximity to

differing electropositive metals such as steel and aluminium may encourage accelerated corrosion. Again this may be compensated for with suitable coating of aramid fibre wraps, but again this would add to the weight and complexity of the barrel.

Careful selection of the winding angle of the fibre, that is to say the angle which the fibre makes to the longitudinal axis of the barrel 12, is also critical to achieving the optimum strength in the barrel. Winding angles between 58° and 72° are currently believed to be the optimum winding angles for Zylon^{tm} fibre reinforced barrels for use with both Aramid and PBO ropes of up to 80 tonne Nominal Breaking Load. Current investigations reveal that for ropes of up to 80 tonne NBL an optimum winding angle within the above range will be determined in accordance with that length of the barrel over which clamping force is applied to the rope fibres in use, the so called "effective length) of the barrel. There appears, in tests, to be a generally linear relationship between the winding angle and the "effective length" when the "effective length" increases from 0 to 100 mm, the optimum winding angle decreasing from 72° down to about 60°. However above the barrel "effective length" of 100mm the angle appears to increase from about 60° to stabilize at about 63° at and above an "effective length" of 160mm. . For ropes having an NBL exceeding 80 tonne, extrapolation of results for ropes of lower NBL suggests that a winding angle range 58° to 72° will still be appropriate. It is to be recognised however that the winding angles given above are suited to the terminator geometry of the present examples, and if departures are made, for example in relation to barrel cone angle then this may dictate a variation in optimum winding angle.

The nature of the epoxy resin material which bonds the fibres together is not particularly critical, provided that it has a sufficiently high glass transition point, to make sure that the epoxy matrix remains solid at the ambient temperatures which the terminator is likely to experience in use, and has a modulus much less than that of the reinforcing fibre. A suitable material is available from Vantico Polymer Specialties under their code name "Araldite® LY5052/Aradur 5052). Suitable vinyl ester resins and other similar matrix materials may be substituted for the epoxy resin.

The wedge member 14 which is introduced into the barrel 12 to clamp the fibres 19 of the rope 18 against the wall of the barrel is conveniently formed from aluminium, is of circular cross-section tapering from a maximum diameter at one end down to a rounded point at the opposite end, conveniently has a length which is 95% of the length of the barrel 12. Adjacent the pointed end of the wedge member 14 the wedge member has a region 14a of steep cone angle. This region takes no part in the clamping of fibres against the inner wall of the barrel 12 and instead serves to assist distribution of the fibres evenly around the periphery of the wedge member 14.

In operation, the wedge member is intended to have its widest diameter end flush with the end 12b of the barrel 12 when subjected to a load equivalent to the Nominal Breaking Load (NBL) of the rope. The wider end of the wedge member 14 can, for convenience, be referred to as the "rear" end and the pointed end can be referred to as the "front" end. In use, measured from the rear end of the wedge member 14, approximately 75% of the length of the wedge member is considered to be "effective length" that is to say it is

considered to be length over which significant and even clamping force is applied to the rope fibres against the inner wall of the barrel 12. Thus measured from the end 12b of the barrel with which the rear end of the member 14 is intended to be flush when the rope is under its design load, the barrel has an "effective barrel length" equal to 75% of the length of the wedge member 14. The minimum required "effective lengths" of the wedge member and the barrel are determined by the taper angle of the inner surface of the barrel, the overall diameter of the fibre hank of the rope to be terminated, the thickness of the barrel, the winding angle of the fibre reinforcement, and the tensile load which the rope and terminator combination is designed to accept.

From the rear end of the wedge member 14 to the point on the wedge member where the steep tapered forward end region commences, the diameter of the tapering internal passage of the barrel 12 decreases. However the total cross sectional area of the fibres to be clamped along this region clearly remains constant, and thus in order to ensure a consistent clamping force along the "effective length" of the wedge member 14 the taper angle of the wedge member must progressively increase so that the area of the annular gap between the wedge member and the inner surface of the barrel 12 remains constant. Furthermore, in order to ensure adequate clamping of the fibres 19 between the wedge member 14 and the barrel 12, the area of the annular gap at any point along the effective length of the wedge member is selected to be less than the total cross-sectional area of the fibres 19, so that the fibres are compressed. In practice therefore the taper angle of the wedge member 14 along its "effective length" is a compound angle, which, during manufacture of the wedge member 14 is determined conveniently at 360

equidistantly spaced points along the length of the wedge member and is then interpolated between those points.

It would be recognised that if desired the taper of the wedge member 14 could be linear, and the compound taper could be applied to the interior of the barrel 12. In practical terms however the later would be much more difficult to achieve than the former, and so it is preferred to have a linear taper in the internal passage of the barrel 12 and a compound taper along the length of the wedge member 14.

As the wall thickness of the barrel 12 is constant throughout its length the outer surface of the barrel 12 tapers at the same angle as the inner surface thereof. The surface finish on the exterior of the barrel 12 is not as critical as the internal finish, but a finish providing an adequate key for epoxy bonding to the body at the rear of the barrel and as a base for providing an aesthetically pleasing finish on the visible exterior surface will be chosen.

The hollow steel body 11 is conveniently formed by machining or forging from a blank of 17 – 4ph or similar stainless steel although any alternative high tensile strength machineable material such as titanium could be substituted. The body 11 is a hollow sleeve of circular cross-section having a cylindrical region 11a at its rear end and a tapering region 11b forming the remainder of the length of the body 11. The tapering region 11b tapers at the same taper angle as the barrel 12 from a maximum diameter at its junction with the region 11a to a minimum diameter at its opposite end.

During manufacture of the terminator the preformed barrel 12 is inserted through the body 11 from the end region 11a thereof until the outer surface of the barrel 12 seats firmly against the inner surface of the body region 11b. An epoxy resin material (conveniently SPABOND® 735) exhibiting high shear strength over the ambient temperature range in which the terminator is to be used, is applied to the interface of the barrel 12 and body 11 after the barrel 12 has been pushed firmly into the body 11 to ensure that the outer tapered surface of the barrel 12 seats firmly against the inner tapered surface of the body 11. It will be recognised that the tapering region 11b of the body 11 supports the corresponding region of the barrel 12 against bursting (hoop) loads imposed thereon in use. The length of the region 11b of the body with an included cone angle of 7.6 degrees is chosen to be a minimum of 60% of the "effective barrel length" although the 60% factor may be varied with terminators offering a different geometry. The thickness of the tapering body section is calculated to withstand the bursting or hoop stresses applied by the barrel in use.

The internal taper angle of the barrel 12 is selected in order to ensure that the rope fibres with which the terminator is to be utilised do not bend through an angle exceeding their FFA at the point where they issue from the barrel 12 and become the main length of the rope. Clearly therefore desirably for optimum performance the included angle of the tapering passage of the barrel 12 should not exceed two times the FFA of the fibres of the rope with which the terminator will be utilised. Where the terminator is to be used with ropes formed from Aramid fibres then the barrel internal taper angle should not exceed 7° and for practical considerations will not be less than 2.5°. The preferred taper angle for Aramid fibre ropes is 3.8° giving a preferred

included angle for the tapering passage of the barrel 12 as 7.6°. Generally, PBO fibres, for example Zylon™ fibres, have a lower FFA than Aramid fibres. Thus a terminator suitable for use with Zylon™ fibres would have a maximum taper angle of 4.5° with a practically determined minimum taper angle of 2°. A preferred taper angle would be 3.8° giving an included angle for the tapering passage of the barrel 12 of 7.6°. In one practical embodiment, a terminator of the kind shown in Figure 2 was designed to be suitable for use with both Aramid fibre ropes and PBO fibre ropes, and had a barrel taper angle of 3.8°, giving an included angle of 7.6° for the rope receiving passage of the barrel.

In order to ensure that the frictional drag between the fibres and the wall of the barrel 12 is significantly less than the frictional drag between the fibres and the outer surface of the wedge member 14 in use, the inner surface of the barrel 12 is maintained as smooth as possible, and the outer surface of the wedge member 14, at least along its "effective length" is roughened by shot or sand blasting or the like. It will be recognised that it is crucial that any tendancy for movement within the barrel when the rope is under its design load is movement of the wedge member and fibres together deeper into the barrel so increasing the clamping force imposed on the fibres. Should the fibres move relative to the wedge member clamping force on the fibres may be lost and the terminator/rope combination may fail.

The rearmost end region 11a of the body 11 receives, as a screw fit, an adaptor 15 formed from stainless steel, and shaped to receive, also as a screw fit, any one of a number of different fixing components 15b (Figure 5) designed to mate with a range of different anchor points. Alternatively an

integrated end fitting, incorporating customised dimensions and non-standard thread to match the body with the final end fixture, could be attached. In either case the body together with either the adapter or the integrated fitting have non-standard threads to ensure 'standard' fittings are not attached directly to the body. The screw thread inside the adapter is designed to attach to standard 'end fixtures' or 'anchor points' to the terminator and is load rated accordingly. The strength of the threaded connection of the fixing component 15b to the adaptor 15 and the strength of the screw threaded connection of the adaptor 15 to the body 11 is sufficient to exceed the maximum design load to be applied to the rope terminated by the terminator. Similarly, the bond between the body 11 and the barrel 12 achieved by the mating taper forms and the epoxy resin provided at their interface, again can accommodate loads in excess of the maximum design load to be carried by the terminated rope. In Figure 4 the adaptor 15 is integral with the fixing component which is in the form of an eye ring 15a.

It can be seen in Figures 2 and 3 that the front end of the barrel 12 is provided with a tapering nosepiece 16. The nosepiece 16 is a moulded synthetic resin component which does not have any significant effect on the termination of the rope, but serves to provide a decorative end to the barrel 12, and to assist in sealing the interface of the terminator and the rope. If desired an 'O'-ring seal 17 can be trapped between the nosepiece 16 and the end of the barrel 12 to grip the rope and so facilitate sealing. Normally the rope 18 will be made up of continuous parallel fibres 19 within a thermoplastic sheath 21. The thermoplastic sheath 21 will extend into the nosepiece 16 and coact with the seal 17, but will terminate thereafter so that the fibres 19 can be fanned out around the steeply tapering front end region

of the wedge member 14 so as to be evenly distributed around the wedge member 14.

Although the invention is particularly concerned with parallel core ropes it is to be understood that the terminator could be used with ropes where the fibres, within the main run of the rope, are wound or braided together, provided that at the end of the rope which enters the terminator the fibres of the rope can be "combed-out" to extend generally rectilinearly and parallel to one another between the wedge member 14 and the inner wall of the barrel 12.

In the examples described above the wedge member 14 has a region which has been referred to as the 'effective length' and which has a composite taper. The length of this region is 75% of the overall length of the wedge member. The remaining 25% of the wedge member is defined by a front end region 14a which tapers steeply. It will be recognised that there is a relatively sharp transition between the forward end of the 'effective length' region and the front end region of the wedge member. In a modification of the wedge member described above a transition zone, integral with the 'effective length' region and the front end region 14a is provided between those regions. The length of the 'effective length' region of the wedge member is reduced to 73% of the total length and the transition zone is arranged to have a length which is approximately 10% of the length of the 'effective length' region, and thus is approximately 7.3% of the overall length of the wedge member. The steeply tapered front end region 14a of the wedge member thus will occupy the remaining 19.7%of the total wedge member length.

Within the transition zone the diameter of the wedge member tapers progressively from the smallest diameter of the 'effective length' region to the maximum diameter of the front end region 14a. This is achieved using an exponential function to give a smooth, and progressive transition between the front end region 14a and the 'effective length' region which permits a progressive 'easing-off' of the clamping force applied to the fibres 19 of the rope 18, by comparison with the sudden removal of clamping pressure at the interface of the two regions in the wedge member described above.

The benefits of providing a transition zone in the tapering wedge member 14 are, the elimination, or significant reduction, of the concentration of stress in the fibres at the end of the 'effective length' region of the wedge member; elimination of a sudden change in the bending angle of the fibres; and, reduction in the differential stress in the barrel of the terminator by increasing that stress progressively over a small proportion of the barrel length rather than going from essentially zero to full loading instantaneously as was the case with the wedge member not employing the transition zone. These benefits translate into a reduction in the possibility of fibre breakage at the high stress points and the ability of the barrel to distribute forces acting thereon over a larger area. Such a modification to the above described arrangement appears to be particularly beneficial in use with PBO cored ropes.

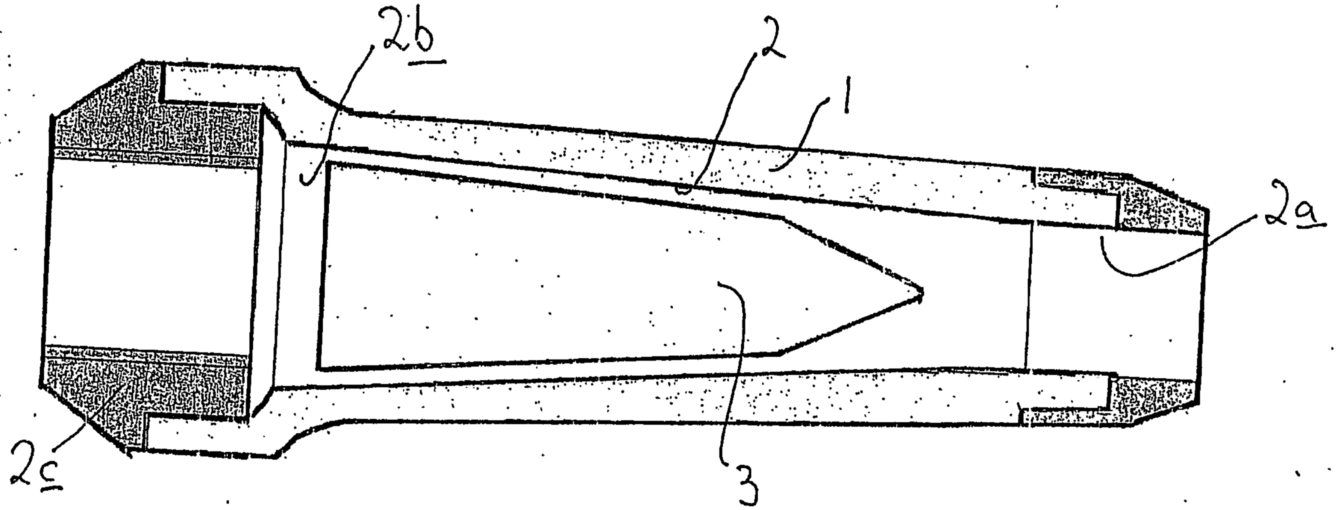

Figure 1

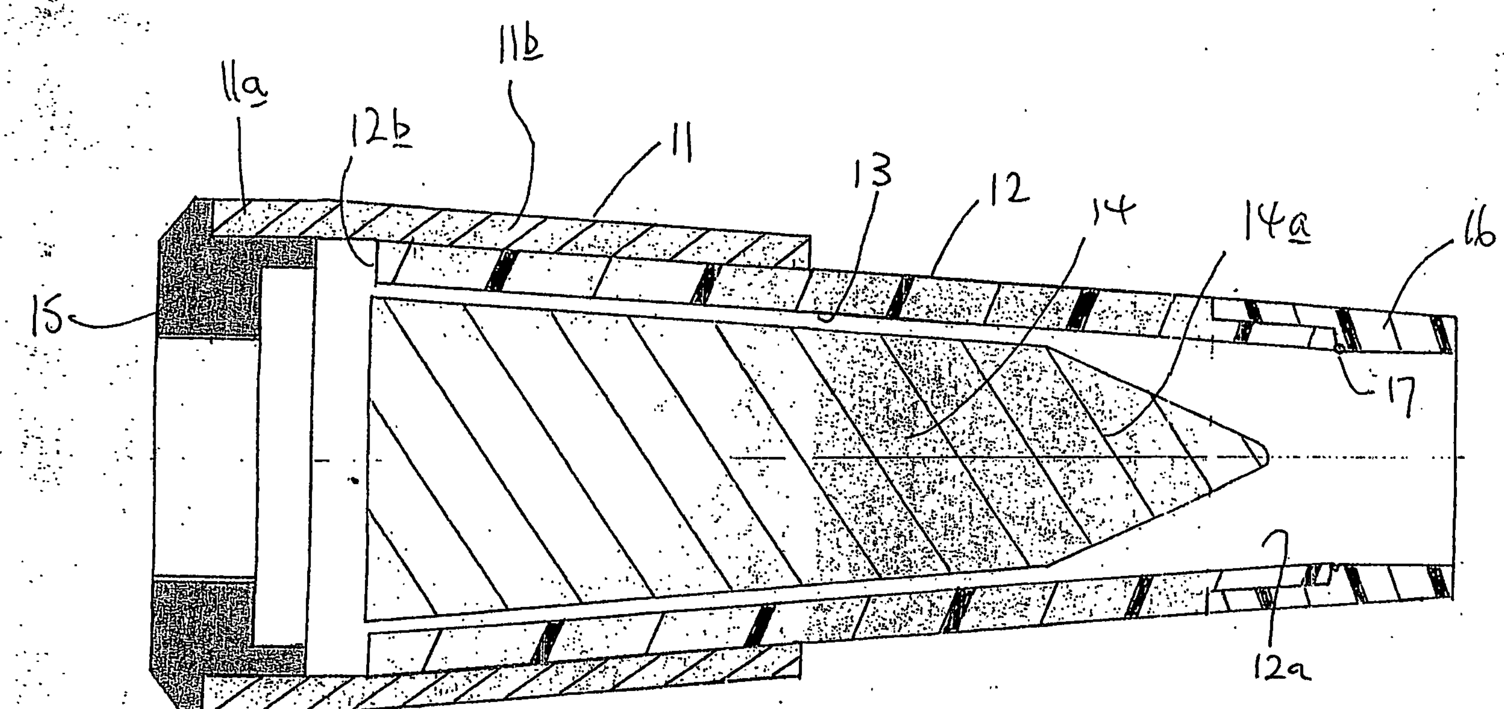

Figure 2

1/11

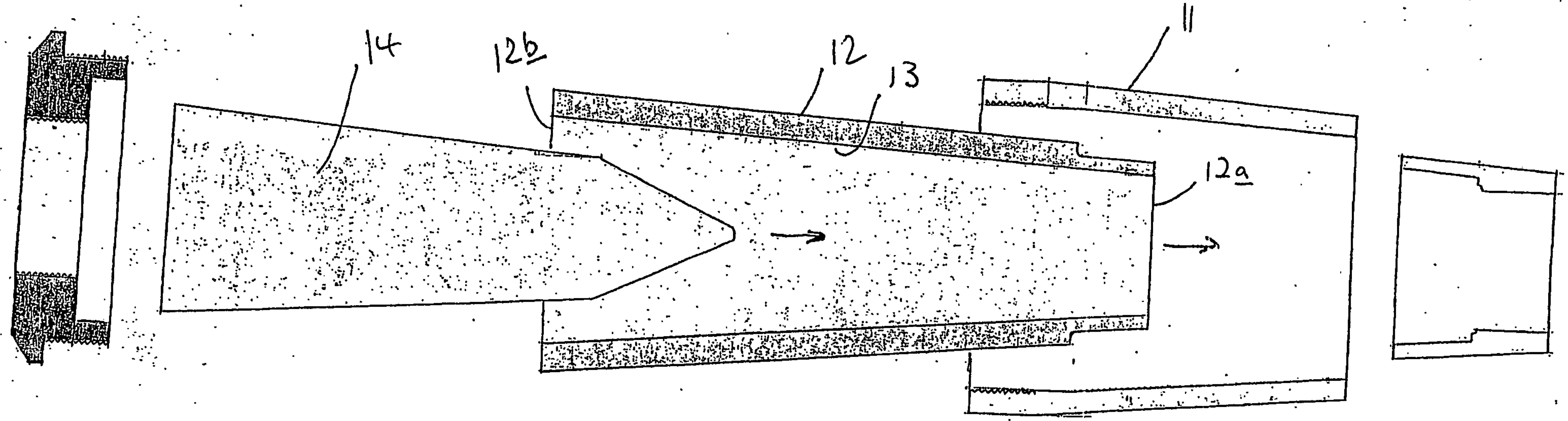

Figure 3

2/4

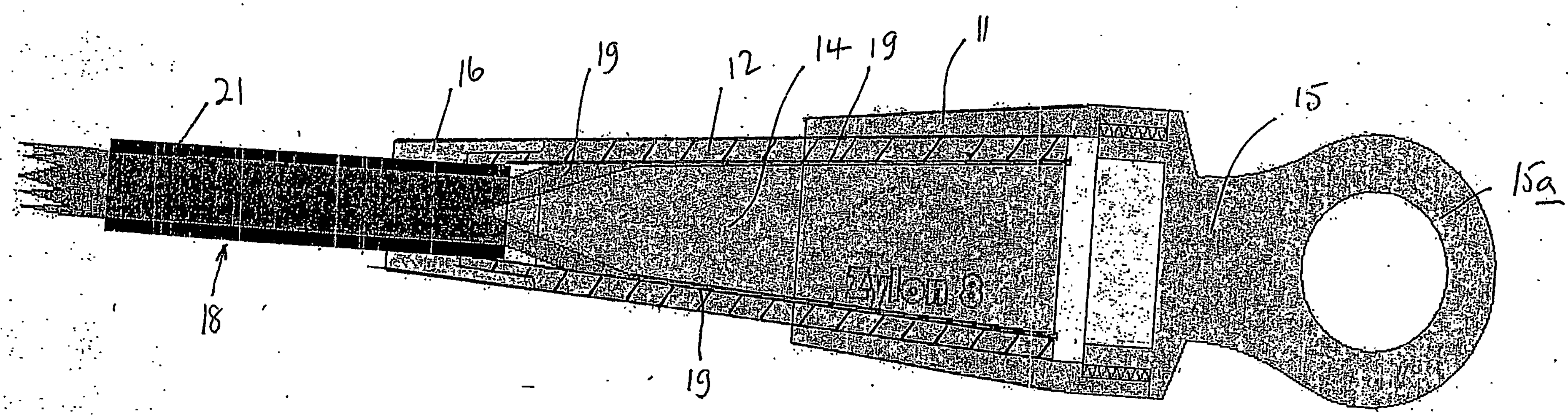

Figure 4

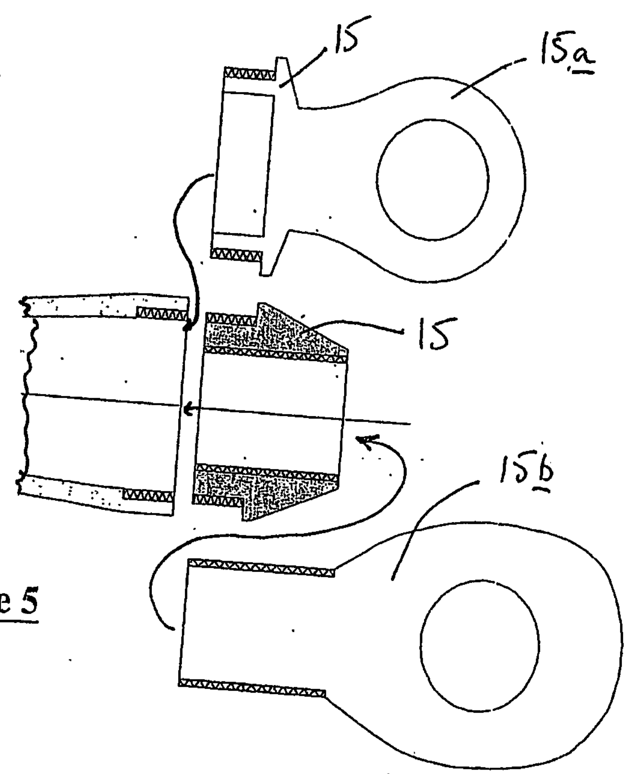

Figure 5

Zylon™ ropes **Body Summary**

size	Q Small End I.D.	H Large End I.D.	T wall thickness	M mating length	L total length
8.0	16.59	21.64	1.79	38.00	48.08
10.0	18.49	23.93	2.00	41.00	52.28
12.0	20.39	26.10	2.19	43.00	55.35
15.0	23.47	29.31	2.45	44.00	57.81
22.5	29.00	35.38	3.00	48.00	64.91
25.0	30.48	36.59	3.16	46.00	63.83
30.0	33.96	41.27	3.46	55.00	74.53
45.0	40.93	49.96	4.24	68.00	91.92
54.0	44.87	54.83	4.65	75.00	101.20
60.0	46.83	57.32	4.90	79.00	106.62
90.0	58.34	71.09	6.00	96.00	129.83
120.0	67.18	81.93	6.93	111.00	150.06
270.0	100.54	122.59	10.39	166.00	224.59

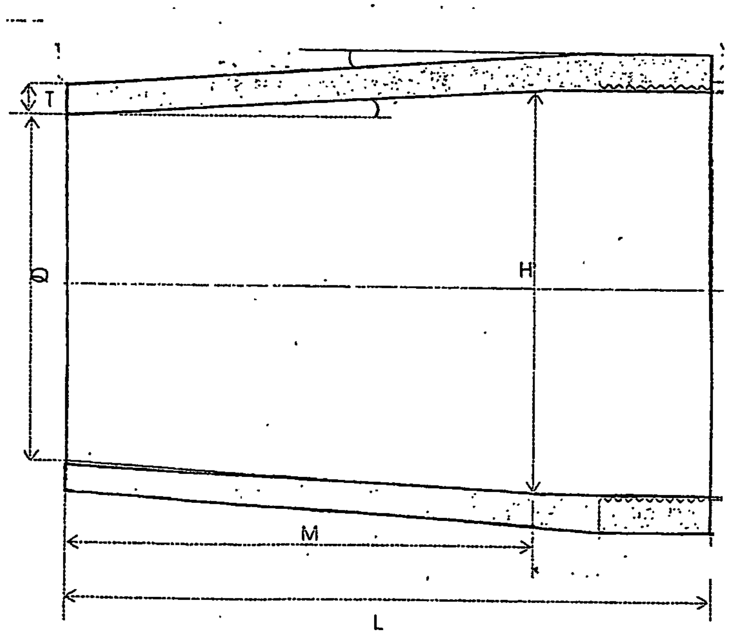

Table 1

Zylon™ Ropes	Barrel summary				
	U	A	G	F	
size	length	Small I.D.	Large I.D.	Wall Thickness	Winding Angle
8.0	63.00	8.80	17.17	2.24	67°
10.0	71.00	9.50	18.93	2.50	66°
12.0	80.00	10.00	20.63	2.74	65°
15.0	88.00	11.50	23.19	3.06	65°
22.5	112.00	13.00	27.88	3.75	63°
25.0	113.00	15.00	28.68	3.95	63°
30.0	125.00	16.00	32.60	4.33	61°
45.0	157.00	18.50	39.36	5.30	60°
54.0	171.00	20.50	43.22	5.81	60°
60.0	185.00	20.50	45.08	6.12	61°
90.0	219.00	27.00	56.09	7.50	63°
120.0	253.00	31.00	64.61	8.66	63°
270.0	381.00	46.00	96.61	12.99	63°

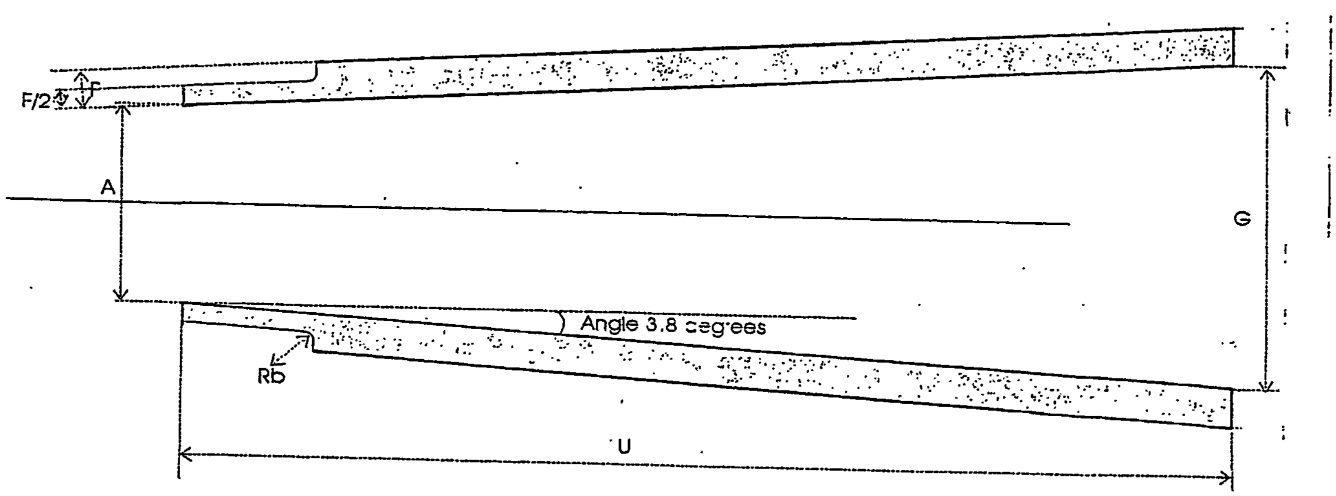

Table 2

Zylon™ ropes

Spike Summary

size	Sc Total Length	Sd Effective Length	Sb Large O.D	Sa Small O.D.
8.0	59.850	44.888	16.516	10.142
10.0	67.450	50.588	18.191	11.007
12.0	76.000	57.000	19.811	11.717
15.0	83.600	62.700	22.283	13.379
22.5	106.400	79.800	26.745	15.414
25.0	97.850	73.388	27.458	17.037
30.0	118.750	89.063	31.314	18.667
45.0	149.150	111.863	37.751	21.866
54.0	162.450	121.838	41.462	24.161
60.0	175.750	131.813	43.206	24.489
90.0	208.050	156.038	53.841	31.683
120.0	240.350	180.263	62.002	36.405
270.0	361.950	271.463	92.690	54.142

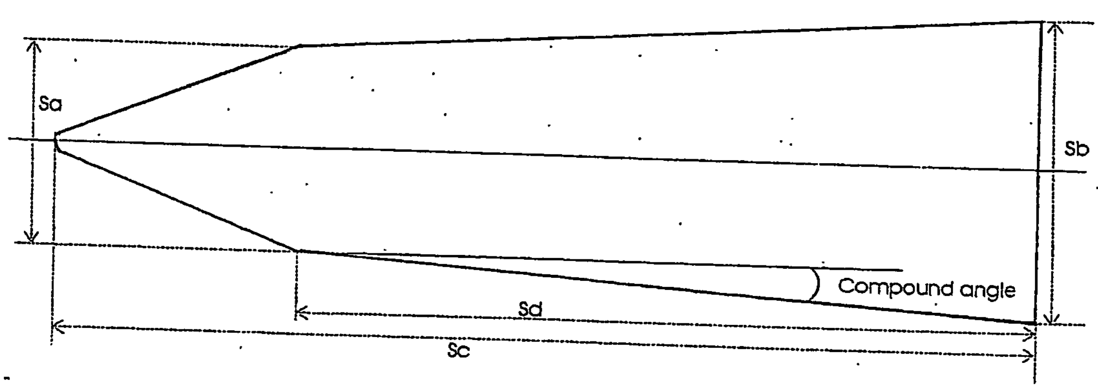

Table 3

Aramid ropes Body Summary

size	Q Small End I.D.	H Large End I.D.	T Wall Thickness	M Mating Length	L Total Length
8.0	18.39	23.18	1.79	36.00	45.17
10.0	20.95	26.00	2.00	38.00	48.25
12.0	23.23	28.41	2.19	39.00	50.23
15.0	26.67	31.99	2.45	40.00	52.55
22.5	32.67	38.52	3.00	44.00	59.38
25.0	34.48	40.59	3.16	46.00	62.21
30.0	38.13	44.77	3.46	50.00	67.75
45.0	47.67	55.64	4.24	60.00	81.74
54.0	52.11	60.88	4.65	66.00	89.82
60.0	54.54	63.84	4.90	70.00	95.11
90.0	64.01	75.83	6.00	89.00	119.75
120.0	74.46	88.01	6.93	102.00	137.51
270.0	115.76	135.42	10.39	148.00	201.26

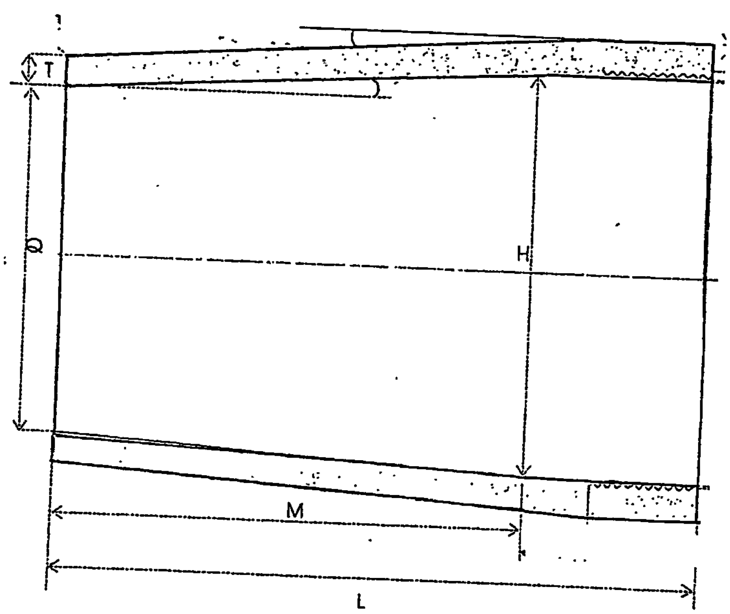

Table 4

Aramid Ropes **Barrel summary**

size	U length	A Small End I.D.	G Large End I.D.	F Wall Thickness	Winding Angle
8.0	58.00	11.00	18.70	2.24	67°
10.0	64.00	12.50	21.00	2.50	67°
12.0	71.00	13.50	22.93	2.74	66°
15.0	78.00	15.50	25.86	3.06	65°
22.5	98.00	18.00	31.02	3.75	64°
25.0	103.00	19.00	32.68	3.95	63°
30.0	110.00	21.50	36.11	4.33	63°
45.0	132.00	27.50	45.03	5.30	60°
54.0	145.00	30.00	49.26	5.81	60°
60.0	155.00	31.00	51.59	6.12	60°
90.0	202.00	34.00	60.83	7.50	62°
120.0	231.00	40.00	70.69	8.66	63°
270.0	327.00	66.00	109.44	12.99	63°

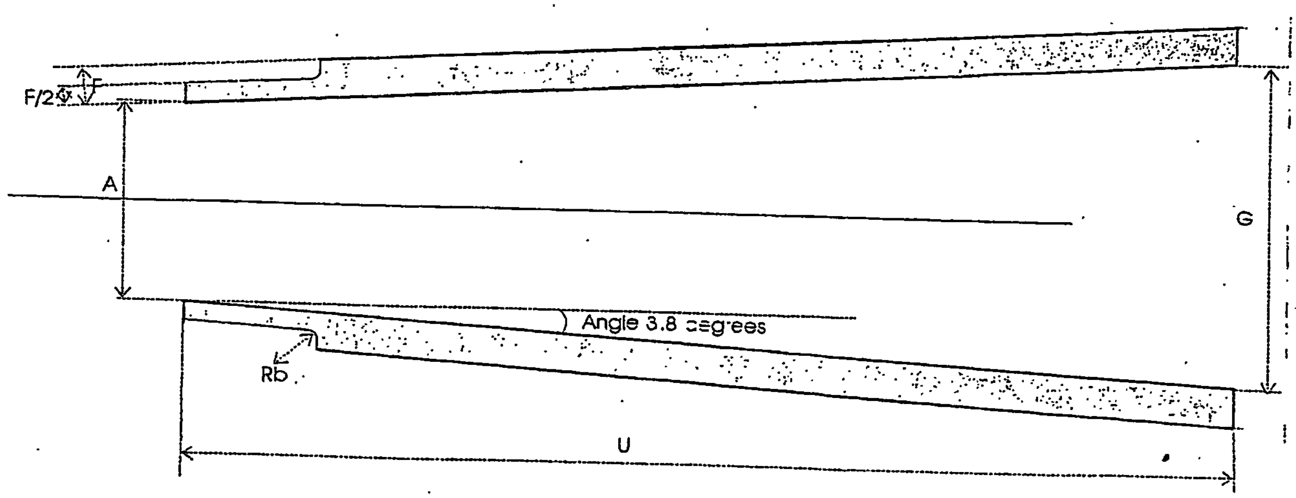

Table 5

Aramid ropes

Spike Summary

size	Sc Total Length	Sd Effective Length	Sb Large End O.D.	Sa Small End O.D.
8.0	55.100	41.325	17.489	11.621
10.0	60.800	45.600	19.649	13.174
12.0	67.450	50.588	21.444	14.261
15.0	74.100	55.575	24.214	16.322
22.5	93.100	69.825	28.955	19.040
25.0	97.850	73.388	30.506	20.085
30.0	104.500	78.375	33.751	22.621
45.0	125.400	94.050	42.198	28.843
54.0	137.750	103.313	46.149	31.479
60.0	147.250	110.438	48.286	32.604
90.0	191.900	143.925	56.619	36.182
120.0	219.450	164.588	65.852	42.481
270.0	310.650	232.988	102.430	69.345

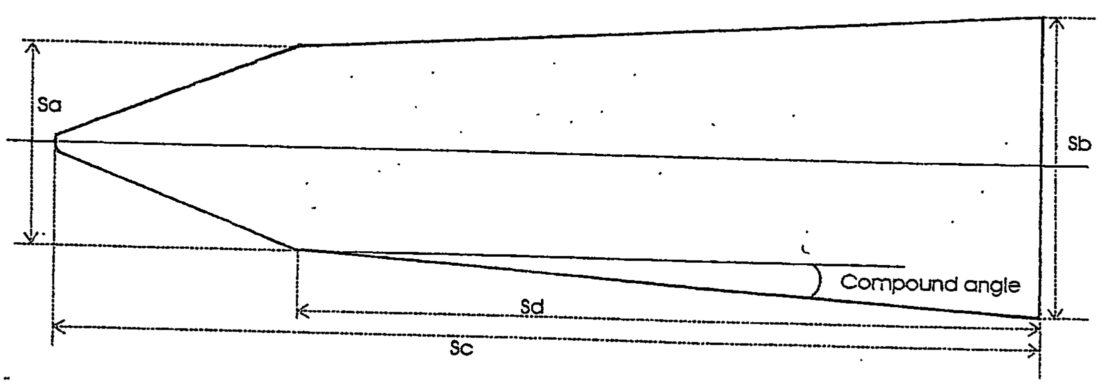

Table 6

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